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UMTRI
Thoraco-Abdominal
Impact Experiments

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Introduction

A test series using unembalmed cadavers is being conducted to investigate thoraco-abdominal impact response and kinematics secondary to steering wheel impact in the laboratory setting. The UMTRI pneumatic impact device accelerates a 65 kg free-traveling ballistic pendulum which is fitted with a steering wheel assembly. A load cell is affixed to the steering column to measure axial steering wheel assembly forces. In addition, string pot transducers mounted at four points on the steering wheel, at one point on the ballistic pendulum, and at one point on the twelfth thoracic vertebra of the test subject record displacements. The test subject is instrumented with 6 accelerometers on the head and 18 accelerometers on the thoracic skeleton. Tests are controlled by an electronic timing device and gross kinematic motion is documented on high-speed film. Induced injury/damage is assessed by gross autopsy.

Steering Wheel Thoraco-Abdominal Impact Testing

UMTRI Pneumatic Ballistic Pendulum Impact Device - The impact device consists of a 65 kg ballistic pendulum mechanically coupled to the UMTRI pneumatic impact device (cannon) which is used as the energy source. The cannon consists of an air reservoir and a ground and honed cylinder with a carefully fitted metal-alloy piston. The piston is connected to the ballistic pendulum with a rigid steel rod and a nylon cable. The piston (Figure 1) is propelled by compressed air through the cylinder from the air reservoir chamber accelerating the ballistic pendulum to become a free-traveling impactor. The ballistic pendulum is fitted with an inertia-compensated load cell which is rigidly mounted to a steering wheel.

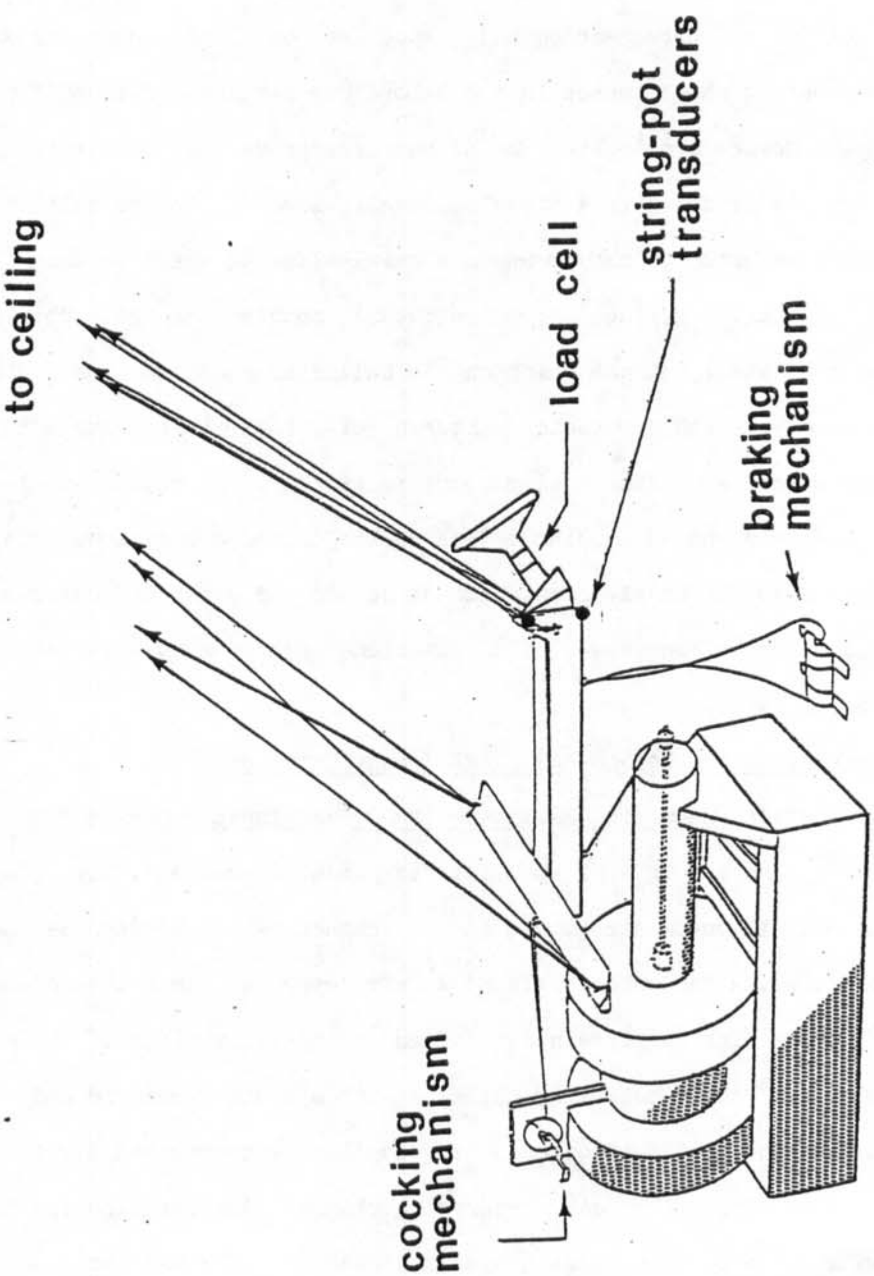
to ceiling
load cell
string-pot transducers
braking mechanism
cocking mechanism

FIGURE 1

The steering wheel angle (defined as the angle formed between a vertical line and a line tangent to the top and bottom of the steering wheel) can be changed in 5° increments in a range of 0°-45°. Either a three-spoke Mustang or Chevrolet Citation steering wheel is used. (See Figure 2.)

Subjects[1]

The unembalmed cadavers used in these experiments are obtained from the University of Michigan Department of Anatomy. When not in use the cadavers are stored in coolers at 4° centigrade. The cadaver is X-rayed as part of the structural evaluation for possible pre-test damage and surgical implants, and anthropomorphic measurements are recorded. The cadaver is then instrumented, sanitarily prepared, dressed in a vinyl and cotton suit, and fitted with a head and a parachute harness (Figure 2).

In the impact laboratory, accelerometers, pressure transducers and phototargets are attached. The subject is placed in a seated position on layers of balsa wood, styrofoam, and friction-reducing clear plastic sheets, and supported via a ceiling mounted rope cutter by the head and parachute harnesses (Figure 2). The lower aspect of the rim of the steering wheel is positioned 11 cm below the sternum (substernale).

Vascular Repressurization

The subject's abdominal vascular system is repressurized just prior to impact. A Kulite pressure transducer guided through the carotid artery, and positioned in the descending aorta just below the diaphragm,

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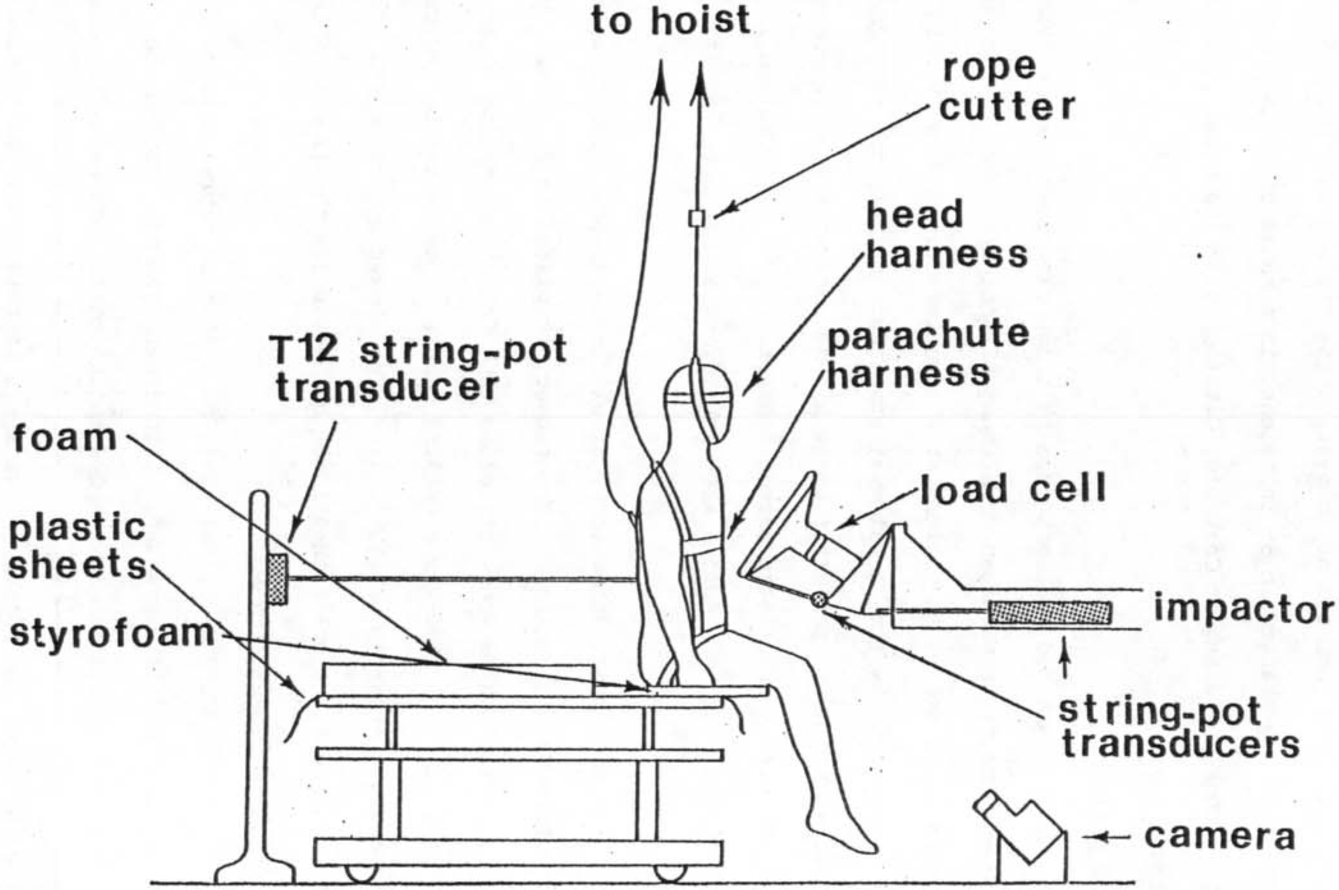
[1]The protocol for the use of cadavers in this study was approved by the University of Michigan Medical Center and follows guidelines established by the U.S. Public Health Service and recommended by the National Academy of Sciences/National Research Council.



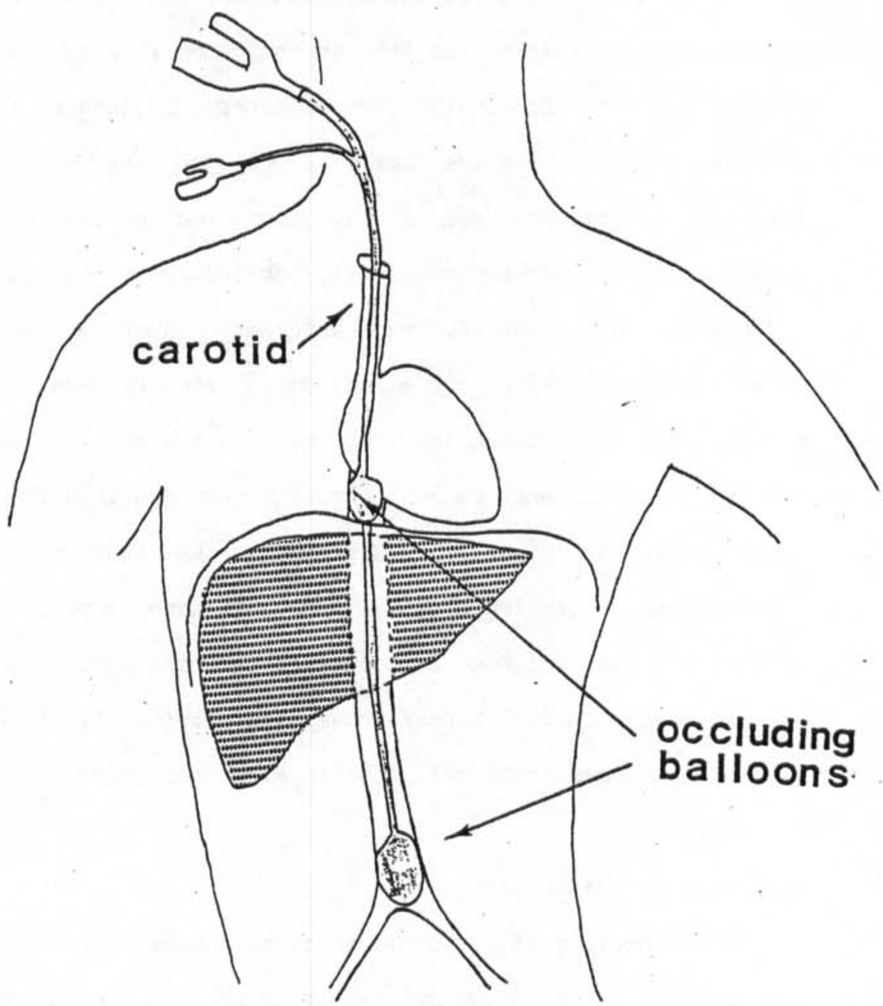
ABDOMEN IMPACT
FIGURE 2

monitors both the degree of initial pressurization and the change in vascular system pressure during impact. The pressurizing fluid is introduced via the catheters through a channel in the center of the two occluding balloons. Both balloons are positioned in the aorta, one above the diaphragm, the other above the aortic termination.

Surgical insertion of the modified catheters follows three patterns depending on whether access through the femoral arteries is possible. Through an incision in the femoral artery, a catheter is guided up the arterial system, where the balloon occludes the aortic termination. Another catheter is guided through an incision in the common carotid artery into the descending aorta, occluding it slightly above the diaphragm. When the femoral arteries cannot be used, due to plaque accumulation, either a double balloon catheter is used to occlude the aorta below the diaphragm and at the common iliac arteries, or two catheters, one in each common carotid artery are used to occlude these same locations (Figure 3). Critical to the study is that the liver be fluid-filled before impact (1,2). This is done by pressurizing the area between the two occluding balloons above normal physiological pressure. One to two minutes before impact the pressure is pulsed between 100-200 mm Hg. Immediately prior to impact the pressure is dropped to 70 mm Hg.

<u>Pulmonary Repressurization</u>

A tracheotomy is performed to place a tube in the trachea, which is connected to a compressed air reservoir so that the pulmonary system can be pressurized to 15 mm Hg. An Endevco pressure transducer is inserted into the trachea to measure the dynamic pulmonary pressure at initial



CATHETER PLACEMENT
FIGURE 3

pressurization and during the change in the pulmonary system pressure throughout the impact.

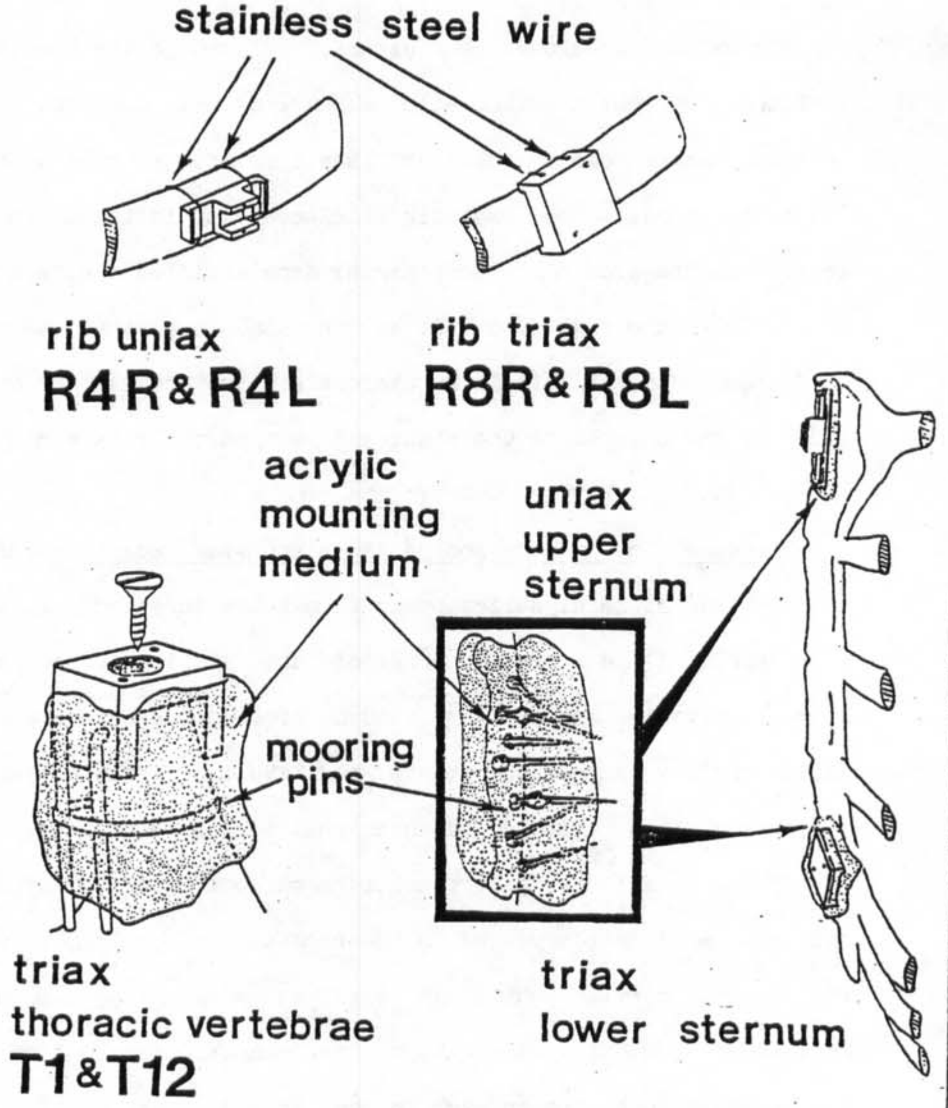
Acceleration Measurement

Triaxial acclerometer clusters, affixed to the head and thoracic skeleton, document the kinematic response of the subject. A pair of triaxial accelerometer clusters is attached to a mounting plate on the subject's head. The thoracic skeleton is instrumented with 18 accelerometers such that the triaxial accelerometer clusters are rigidly attached to the right and left eighth ribs, lower sternum, and thoracic vertebrae 1 and 12. Single accelerometers are affixed on the lateral side of the cadaver to the right and left fourth ribs and upper sternum (Figure 4).

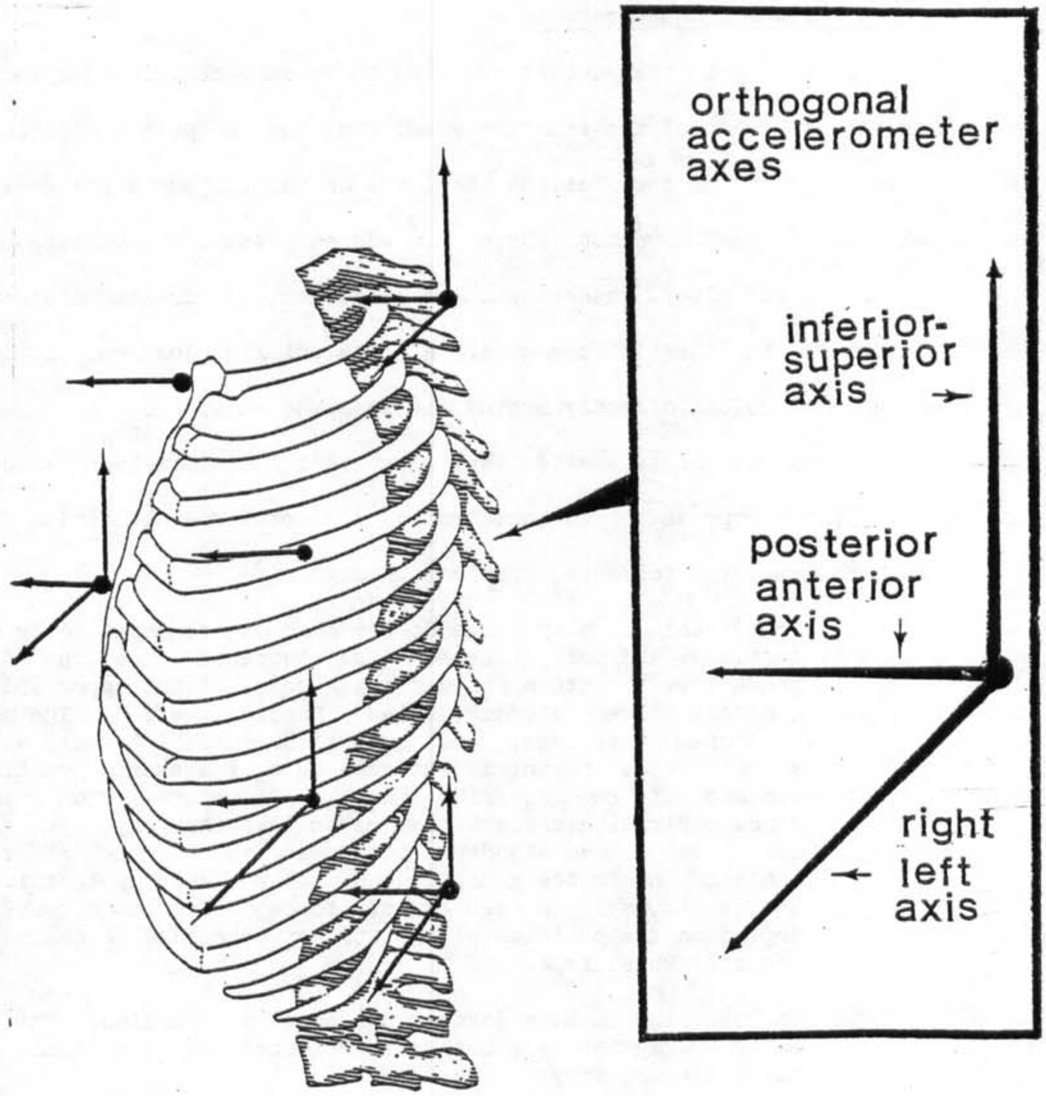
Surgical Instrumentation of Accelerometer Mounts - For the head mount, several metal self-tapping screws are threaded directly into the right parietal and occipital bones of the skull through small pilot holes. Plastic acrylic is molded around the screws and a mounting plate, rigidly attaching it to the skull. Triaxial accelerometer clusters are then attached to their positions on the plate.

Skin incisions expose the attachment points on the upper and lower sternum. Small nails placed in the exposed sternum form a mooring for the dental acrylic which is used as a mounting medium for the accelerometer mounts. For rib mounts, incisions are made over the fourth and eighth ribs on each lateral side so that the flat part of the rib is exposed. To ensure rigidity, the mounts are fitted with pins and tied with wire to the flat surface of each exposed rib.

For the T1 and T12 spinal vertebral mounts, deep incisions are made so that lateral supports for the accelerometer mounts are anchored on



ACCELLEROMETER
MOUNTING PLATFORMS
FIGURE 4



ACCELLEROMETER
AXES
FIGURE 5

the lamina bilaterally. Acrylic is applied under and around the mounts to ensure rigidity (Figure 5).

Force Deflection Measurement

String pot transducers are used to measure pendulum displacement, the lowest point of the steering wheel rim, and a point opposite the lowest point on the steering wheel rim on the subject's spine (located at T12). The impactor force transducer assembly consists of a piezoelectric load washer with a piezoelectric accelerometer mounted internally for inertial compensation. The uniaxial load cell is located on a rigid column directly behind the steering wheel hub.

The above measurements may give useful information about the kinematic response of the abdomen in terms of force deflection (Figure 6). However, the following problems exist:

1. The structural properties of the abdomen are mediated by bone, cartilage and soft tissue. The thoracic cage can form a protective structure for various aspects of the upper abdominal contents (liver, stomach, spleen, pancreas, etc.). The portion of bone, cartilage, and soft tissue that interacts with the steering wheel during impact depends on the exact position of contact of the steering wheel. Therefore, to describe the force deflection characteristics so that they may be useful in terms of understanding the response of the abdomen or contributing to the construction of an anthropomorphic test device (dummy), a series of force deflection curves, which depend on the position of impact, may be needed to characterize steering wheel impact.

2. The steering wheel undergoes permanent deformation. This activity may not be accurately reflected in the load cell's force time history.

3. Initially during the impact event, the soft tissue of the abdomen dominates external input to the steering wheel assembly. At some time during the impact event as the test subject rotates forward, the head, shoulders and upper thorax also make contact with the steering wheel affecting the force time history.

4. Loading of the steering wheel rim is not necessarily accurately represented under all conditions by the force measured at the center of the steering wheel.

"HEMIDEMISEMIPSEUDO"
FORCE-DEFLECTION
CURVE
for 83E121-C

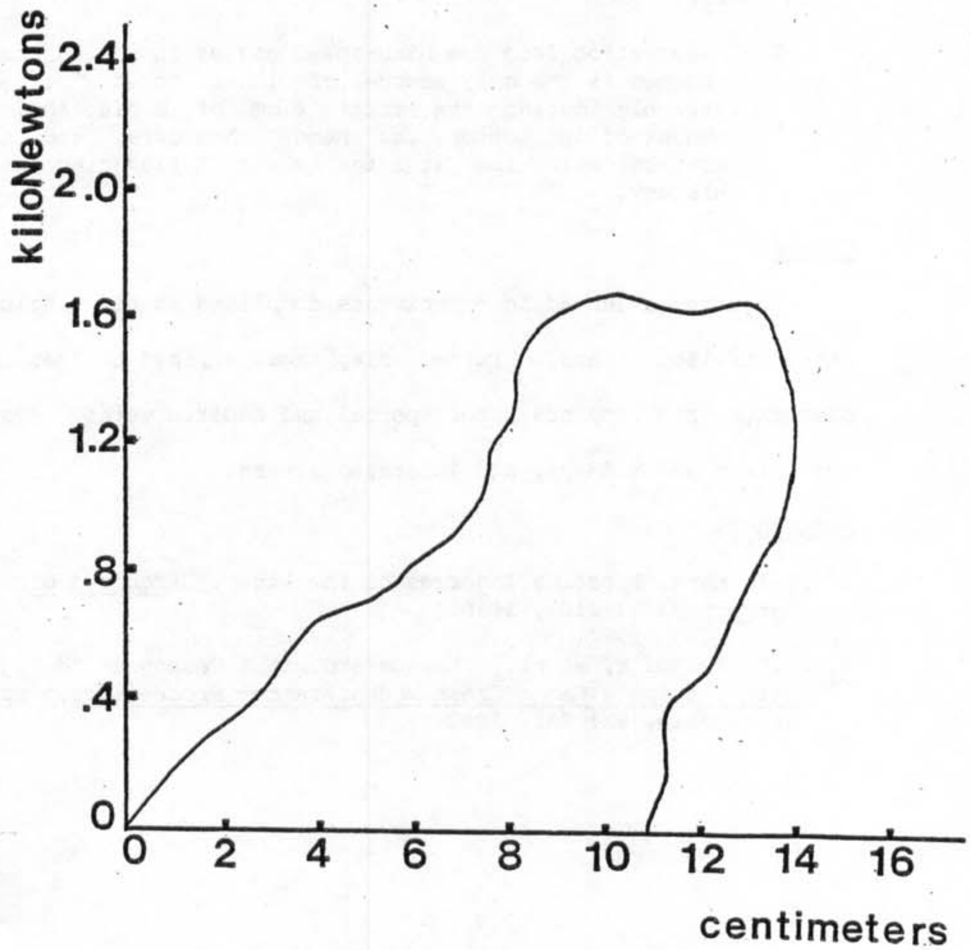


FIGURE 6

5. The motion of the test subject is three-dimensional. This may lead to inaccuracies when using one-dimensional transducers such as string pots.

The initial segment of the force deflection curve (up to 4 cm deflection) serves to represent the most usable portion of the curve. This is a result of the following:

1. In both dynamic and quasi-static testing, the force at the steering wheel rim was within 15 percent of that at the steering wheel center for deflection up to 4 cm of the lower aspect of the steering wheel rim for experiments completed so far.

2. Observation from the high-speed movies indicates that the abdomen is the only source of input to the steering wheel assembly during the first 4 cm of deflection. After that amount of deflection, the head, shoulders, and thorax make contact with the steering wheel influencing the force time history.

Trauma

Injuries observed in experiments completed so far include: broken ribs, bruised lungs, bruised diaphragm, striped bruises on liver and diaphragm (rib imprints), torn portal and hepatic veins, contusions of the spleen and kidneys, and lacerated livers.

References

1. E.T. Mays, Bursting Injuries of the Liver. Archives of Surgery 93(92):103, 1966.

2. G.S. Nusholtz, et al., Thoraco-Abdominal Response and Injury. 24th Stapp Car Crash Conference Proceedings, pp. 187-228, Warrendale, PA: SAE, 1980.